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~~ELLIPSOMETER MEASUREMENT APPARATUS.~~

FIELD OF THE INVENTION

~~Background of the Invention~~

The present invention ~~refers~~ relates to an ellipsometer measurement apparatus for determining the thickness of a film applied on a substrate, ~~having~~. The apparatus includes a light source emitting an incoming beam, a transmitting optical system conveying the polarized incoming beam to an incidence point on the substrate, and a receiving optical system that has an analyzer and conveys the reflected beam formed at the incidence point to a photodetector device~~, the~~. The polarization direction of the incoming beam and of the analyzer ~~being~~ are modified in time relative to one another, and the intensity changes produced thereby ~~being~~ is evaluated by way of an evaluation device in order to determine the film thickness.

BACKGROUND INFORMATION

An ellipsometer measurement apparatus ~~of this kind is~~ described in Bosch Technische Berichte, Vol. 4 (1974), No. 7, pages 315-320. It is possible with a measurement apparatus of this kind, for example, to measure the thickness of protective films on aluminum-coated headlight reflectors in the form of a paraboloid mirror with a large aperture ratio; the film thicknesses are in the range from 10 to 50 nm, and a resolution on the order of a nanometer is achievable. For this purpose, a polarized incident beam is directed at a predefined angle of incidence onto a measurement point of the headlight reflector, and is reflected at an angle that is also predefined. The reflected beam is elliptically polarized, and for determination of the ellipticity is conveyed through a rotating analyzer onto a photodetector on which intensity fluctuations of the light signal that correspond to the ellipticity are sensed. The ellipticity and thus the change in intensity depend on the film thickness, so that the latter can be determined in a

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downstream evaluation device. The angle of the incident beam and reflected beam in terms of the tangential plane or the normal line at the measurement point is often difficult to establish, and accurate adjustment is almost impossible at difficult-to-access locations or with changing curvature profiles, as in the case of modern headlights.

~~Advantages of the Invention~~ SUMMARY

It is ~~the~~ an object of the present invention to ~~make available~~ provide an ellipsometer measurement apparatus ~~of the kind recited initially~~ that, while easy to adjust and handle, supplies accurate measurement results even at difficult-to-access locations and with differing curvature profiles.

~~This object is achieved with the features of Claim 1.~~ Insert a2

According to ~~this,~~ an angle measurement device is provided with which the angle of the reflected beam relative to a tangential plane of the substrate at the incidence point can be sensed, and the film thickness can be determined by way of the evaluation device as a function of the angle that is sensed. Because the angle of the reflected beam is sensed and is additionally evaluated in order to calculate the film thickness, the measurement apparatus can easily be placed on the film and the measurement can readily be performed. The resulting angle is automatically and accurately taken into account, and is incorporated into the calculation of the film thickness using conventional algorithms ~~known per se~~.

Measurement of the angle can also be accomplished in simple fashion by the fact that the angle measurement device has a photodetector unit that is position-sensitive in the X and/or Y direction, as well as an evaluation stage with which the angle of reflection can be calculated from the position data and from distance data. Experiments have shown that even a one-dimensional angle determination yields good measurement results for the film thickness.

The simple configuration is promoted by the fact that the intensity changes and the position of the reflected beam are sensed with the same photodetector of the photodetector device.

A further possibility for easy determination of the angle consists in the fact that the photodetector device has two position-sensitive photodetectors arranged at different distances from the incidence point in the beam path of the reflected beam, and that the angle is calculated on the basis of the differing positions of the reflected beam on the two photodetectors. Here again, one of the photodetectors can be utilized simultaneously to measure the intensity changes of the reflected beam.

When the angle is determined using two photodetectors, the configuration can be, for example, such that a beam splitter is arranged in the beam path of the reflected beam in front of the two photodetectors, and that each photodetector receives a partial beam of the reflected beam. Alternatively, the two photodetectors can also be arranged one behind another, a portion of the reflected beam passing through the front photodetector.

If only one photodetector is used, provision is advantageously made for a converging lens to be arranged in front of the photodetector device.

Simple handling is promoted by the fact that the transmitting optical system and the receiving optical system are integrated into a common carrier, and that the carrier has a three-point support for placement on the film. With this configuration, unequivocal placement on the film is also always guaranteed. The three-point support can comprise, for example, a ball support which on the one hand guarantees single-point support at the three support points and on the other hand prevents damage to the film.

In order to obtain reliable measurement results, it has proven advantageous to use a configuration in which the transmitting optical system has a polarizer and a λ/4 plate in the beam path of the incoming beam, and the polarizer or the analyzer is arranged in rotationally drivable fashion about an axis normal to its surface.

~~The invention will be explained below in more detail with reference to exemplary embodiments, referring to the drawings in which:~~

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a schematic depiction of an ellipsometer measurement apparatus in a partially sectioned side view~~; and~~.

Figure 2 shows a side view of a further ellipsometer measurement apparatus.

DETAILED DESCRIPTION

Figure 1 shows a measured object 1 made up of a substrate and a film, applied onto the concavely curved inner side thereof, whose thickness at a measurement point P is to be measured using a measurement arrangement 2.

Measurement arrangement 2 possesses a laser 3, a lens 4 in front of the latter, a light guide 6, a measurement probe 5, and an evaluation device 7. The light beam generated by laser 3 passes through front-mounted lens 4 and light guide 6, as incoming beam 9, into measurement probe 5, and is directed by the latter, through a transmitting optical system having a lens 5.1, a polarizer 5.2, and a λ/4 plate 5.3, onto the measurement point or incidence point P of measured object 1.

The beam reflected at incidence point P, in the form of reflected beam 10, passes, in a receiving optical system, through a rotationally driven analyzer 5.4, a filter 5.5, and a converging lens 5.6, and is focused by the latter onto a photodetector 5.7. Photodetector 5.7 belongs to a

photodetector device that detects on the one hand intensity fluctuations of reflected beam 10, and on the other hand the incidence location on photodetector 5.7. Photodetector 5.7 can be, for example, a position-sensitive detector (PSD) or a CCD camera. A position measuring instrument 7.1 for an X and/or Y position is provided in evaluation device 7. The distance from incidence point P is taken into account when the X and/or Y angle is calculated. Also provided is an intensity measuring instrument 7.2 that senses the intensity fluctuations of reflected beam 10 resulting from the rotation of analyzer 5.7 and serves to calculate the ellipticity.

From the ellipticity, and taking into account the reflection angle ascertained from the X and/or Y angle, the film thickness can be determined using conventional algorithms ~~known per se~~. In this context, empirical tabulated values that are stored in a memory can also be utilized, for example, to determine the film thickness.

Whereas in the configuration according to Figure 1 the same photodetector 5.7 is used to measure the intensity change and to calculate the angle, with the otherwise corresponding configuration according to Figure 2, two photodetectors 5.7 and 5.8, at different distances from incidence point P, are provided for determination of the angle. Reflected beam 10 is split at a beam splitter 5.9 into two partial beams that pass along different path lengths before reaching the associated photodetectors 5.7 and 5.8. From the different X and/or Y positions on the two photodetectors 5.7 and 5.8, the X and Y angles (and from them the angle of reflection) can be ascertained as a function of the different path lengths. One of the two photodetectors 5.7 and 5.8 can simultaneously be utilized for the intensity measurement. Figure 2 also shows the angle α of incident beam 9 with respect to a tangential plane at incidence point P, the angle ~~[beta]~~ β of reflected beam 10 also with respect to the

tangential plane, and an angle ~~[gamma]~~ γ between the incident beam and reflected beam.

Instead of analyzer 5.4 shown in Figure 1 that is rotatable about a surface normal line, ~~said~~ the analyzer can also be replaced by a stationary analyzer and instead a rotating polarizer 5.2 can be provided in the transmitting optical system. It has been found that the reliability of the measurement results can thereby be improved.

The transmitting optical system and receiving optical system are installed in a common carrier that is equipped with a three-point support, for example preferably in the form of balls or spherical caps, thus attaining unequivocal placement of the measurement apparatus on measured object 1 even at difficult-to-access points and when different curvatures are present. The measurement apparatus, being a probe, is easy to handle, and is simple to adjust because the angle of the reflected beam is automatically sensed.